A NEW DASYCLADACEAN ALGA, *NANOPORA*, FROM THE LOWER CARBONIFEROUS OF ENGLAND AND KAZAKHSTAN

by ALAN WOOD

ABSTRACT. *Nanopora*, a new genus of dasycladacean algae, is found abundantly in the Yoredale limestones at Hardrow Scar, Yorkshire, and in the uppermost D_1 of the Avon Gorge. Specimens from Kazakhstan have previously been described by Maslov (as *Anthracoporella*).

THOUGH dasycladacean algae were previously considered to be inexplicably absent in Lower Carboniferous rocks (Garwood 1931), ten genera have now been found in rocks of this age. One, *Koninckopora*, has been recorded from Europe, North Africa, North America, and Japan, apparently being restricted to rocks of Visean age. Other genera occur more sporadically, presumably because they lived within a narrow range of conditions in shallow clear waters. The present genus occurs in considerable abundance in the Hardrow Scar Limestone (D_2) at Hardrow Scar, in the uppermost D_1 of the Avon Gorge and, very probably, in the Lower Carboniferous of Kazakhstan.

The Dasycladaceae are green algae, fixed to the substratum and therefore indicative of shallow water. Their thallus consists of a large elongated central cell around which radiate branch-like prolongations which vary in form from genus to genus. A calcareous precipitate may envelop the branches, wholly or in part, and, more rarely, the outer wall of the central cell. The calcareous structure preserved in the fossil state is therefore an external mould of part of the plant. It generally has the form of a hollow tube pierced by numerous pores. Diagrams illustrating the general structure of Dasycladacean algae may be found in Pia (1927), Wood (1941), and Rezak (1959).

NANOPORA gen. nov.

Diagnosis. An elongate dasycladacean alga, subcylindrical in form, rarely bent or twisted, probably expanding in diameter gradually with growth. The central cell apparently unbranched and usually unconstricted. Branchlets departing from the central cell at an angle of 90°, arranged in equally spaced verticils, the number of branchlets varying with the age of the specimen, generally about twenty to forty. Branchlets in successive verticils alternating with those above and below. The shape of the branchlets as seen in longitudinal sections varies with the amount of calcification, in general they widen outwards and are somewhat widely separated at the level of calcification, tending to be elliptical in transverse section with the long axis of the ellipse parallel to the growth axis of the plant.

Remarks. The branchlets do not divide within the thickness of the calcareous envelope in any of the present specimens. The thickness of the calcareous precipitate varies, perhaps with the age of the fragment observed, and in specimens with a thin calcareous layer the branchlets may appear parallel sided. The walls are neither fibrous nor granular but consist of clear calcite crystals of varying size and irregular outline which are often

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continuous from the outer to the inner wall and may extend laterally to enclose several pores. They resemble the crystals making up the wall of *Coelosporella*, which have been interpreted as being formed by recrystallization of a precipitate of aragonite (Wood 1940). The Yorkshire specimens are contained in a very fine-grained limestone, while those from the Avon Gorge are surrounded by a coarse matrix, probably recrystallized. The specimens from the Avon Gorge also show a fine-grained outer coating, interpreted as a post-mortem precipitate.

The structure of this genus contrasts strongly with that of *Koninckopora*, the other common Lower Carboniferous dasycladacean alga. In the latter the wall is formed of minute grains of calcite, probably still nearly as originally precipitated, except for grain growth, and the branchlets are irregularly placed, closely adpressed, and become polygonal in shape by mutual pressure. In the regular arrangement and spacing of the branchlets *Nanopora* carries further a tendency seen in *Primicorallina* of the Silurian and in this feature resembles the Mesozoic rather than the Palaeozoic members of the Family. *Koninckopora* on the other hand retains the irregularity of arrangement seen in such a form as *Mastopora*.

The strictly symmetrical arrangement of branchlets in verticils transverse to the axis of growth is unusual in the Palaeozoic,[1] though the cylindrical form is seen in *Rhabdopora* of Silurian age. In the symmetry of its branching *Nanopora* resembles Triassic members of the Diploporae, but can be separated from them by its small size and the shape and spacing of the branchlets. Certain Permian forms figured by Endo (1961) as *Gyroporella* resemble the present genus in the regular arrangement of their branchlets, but the shape of the branches is different, and the specimens are nearly ten times as large. The only previous record of the present genus is due to Maslov (1939) who illustrated three specimens (as *Anthracoporella fragilissima*) from the Lower Carboniferous. They differ from *Anthracoporella* in the regular arrangement of the branchlets and their less close packing. The maximum known diameter of specimens of this genus is also thirty times less than the maximum in *A. spectabilis* Pia, the genotype. The genera described by Korde (1950) Maslov and Kulik (1956) and Chvorova (1949) from the Lower Carboniferous of the U.S.S.R. are all clearly different from the present form.

The generic name refers to the small size of the thallus, the specimens being among the smallest Dasycladaceae known.

Nanopora anglica sp. nov.

Plates 31, 32

Diagnosis. Diameter of calcareous tube ranging generally from 0·1 to 0·17 mm., occasionally up to 0·20 mm. Pores in well-grown and lightly calcified specimens slightly elliptical, external transverse diameter 0·01 to 0·013 mm., occasionally reaching 0·015 mm.; diameter parallel to axis of growth 0·012 to 0·018 mm. Verticils equally spaced, from five to seven in 0·1 mm. in well-grown specimens. Calcareous tube circular in cross-section, typically straight, increasing in diameter very gradually. The central lumen of the calcareous tube generally parallel sided in the short longitudinal sections available,

[1] The forms described as *Verticillopora* and *Phragmoporella* by Rezak (1959) from the Silurian, supposed to show this feature, are probably not algae, as I hope to show in a later communication.

rarely a sudden increase in diameter followed by a constriction occurs. Branching not observed.

Remarks. The specimens occur in abundance in a dark fine-grained limestone, and are obviously portions of broken elongated tubes. The longest fragment observed measures 1·3 mm. Sections of fragments cut parallel to the outer wall (Pl. 31, fig. 3) show that the pores are truly elliptical, a fact which could not be conclusively demonstrated in oblique sections like those on Plate 31, fig. 1. Some specimens, however, have circular pores, and even elliptical and circular ones may occur in the same fragment. A similar variation is seen in the shape of the pores in longitudinal section, some are parallel-sided as they traverse the wall of the tube, others widen towards the exterior (the commonest case) and some widen and contract again so that they appear club-shaped.

The ratio of the diameter of the interior lumen to the external diameter of the calcareous tube, often considered to be of importance in the fossil Dasycladaceae, varies considerably in this species, ranging from 40 to 60 per cent. according to the degree of calcification. There is some evidence that the degree of calcification, that is the thickness of the wall of the tube, was greater in the older parts of the plant, and in thick-walled portions the pores may appear smaller and be more indistinct, possibly because the branchlets were here more flaccid. Tubes of large diameter may be thickly calcified, however, and as shown in Plate 32, fig. 1, may show what can be interpreted as the growing point of the plant, so that there was probably variation in degree of calcification from plant to plant.

Oblique cross-sections such as those shown in Plate 31, fig. 1, yield the most information. In such sections the external and internal diameter of the tube can be accurately obtained, and at the ends any variation in diameter of the branchlets as they passed from the interior of the tube to the outside is clearly visible. The number of rows of verticils in 0·1 mm. can be measured on the side of the section and checked by direct measurement on the obliquely cut ends of the tube. It is quite common to find that the pores are slightly larger in diameter at one end of the elongate obliquely cut section than at the other (Pl. 31, fig. 1). On cross-sections the number of branchlets in one verticil can be estimated, but never very accurately because it is difficult to be certain that the pores counted belong to one verticil only. The number of branchlets in a verticil appears to have varied from 20 to 30; some specimens with 40 or more pores are considered to belong to another species.

One section shows an expansion of the central cell, followed by a constriction (Pl. 32, fig. 2), and this condition is more indistinctly seen in four other specimens. The arrangement of the pores radiating upwards around the constricted portion indicates that the growth of the branchlets was affected by this variation in diameter of the central cell and proves that this is an original feature connected with the growth of the alga. Its significance is unknown. Other sections (Pl. 31, fig. 2) show that the alga was, rather rarely, flexed. The difference in the two ends of the specimen shown in Plate 32, fig. 1, either indicates that the calcified tube was quite sharply bent with one end turning down out of the plane of the section, or shows the actual growing point of the plant.

In some portions of the rock sections traces of small calcified tubes without pores are seen (Pl. 32, fig. 3). These are composed of crystals of calcite similar to those making up the calcified tubes of *Nanopora*, and are quite different in structure from the concentrically laminated spines of *Productus*, which also occur in this rock. None of these tubes has been seen attached to *Nanopora*, but it is considered that they may well be portions of the calcified holdfasts of this plant.

There is considerable variation in the pore diameter and spacing of the verticils among the specimens studied. There appears to be a complete range of variation from the well-grown specimens described above, to specimens with a pore diameter ranging from 0·04 mm. (interior) to 0·07 or 0·08 mm. (exterior) and the number of verticils in 0·1 mm. may rise to as high as nine in these specimens. Part of this variation may certainly be due to age of the specimens, but the pore size is not strictly dependent on the diameter of the tube, and a real variation in these features is certainly present, which renders it difficult to define the boundaries of the species. The work of Egerod (1952) shows how variable the degree of calcification and the form of the thallus can be in modern Dasycladaceae.

Type specimen. That shown in Plate 31, fig. 1. Deposited in the British Museum (N.H.), registered number V.45813.

Locality and horizons. Hardrow Scar Limestone, top bed, Hardrow Scar, near Simonstone, Yorkshire (D_2), also at New Close Sike, Raydale (south of Semerwater), and Coal Sike, Siley Gill, Swaledale. National Grid References SD869918, SD893848, SD900978. Also with *Girvanella wetheredii* in a bed of dark limestone with argillaceous material, 9 inches thick, immediately below an oolitic bed 10 feet thick, a short distance below the junction of the road from Clifton with that along the banks of the River Avon, Bristol (Upper D_1). National Grid Reference 31/563734.

Nanopora fragilissima (Maslov)

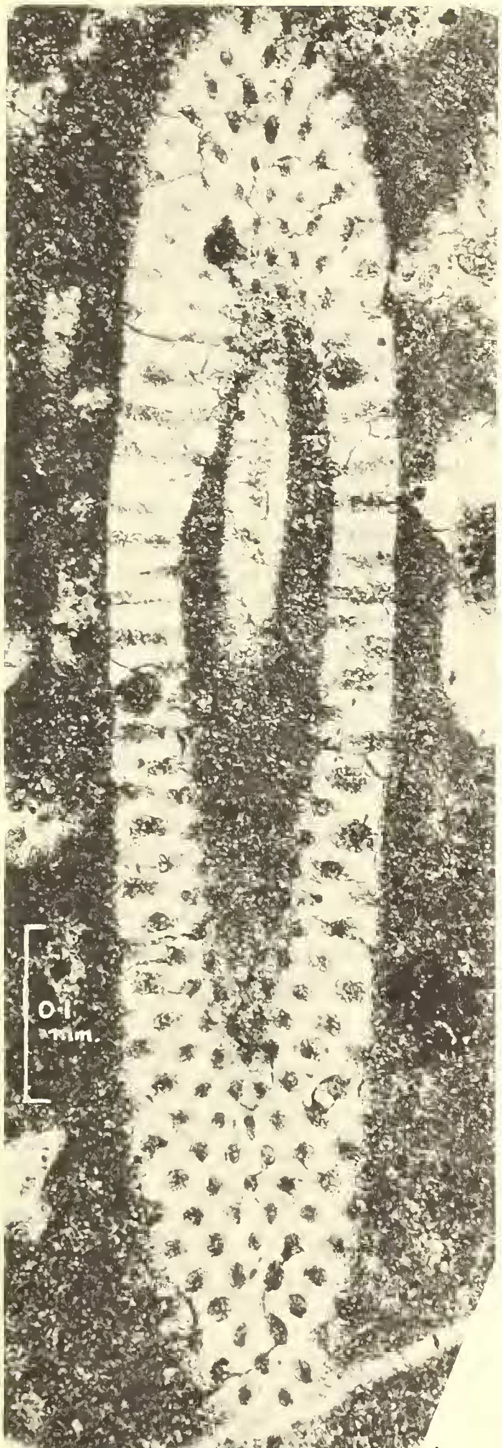
Original diagnosis. Cylinders straight with the outer diameter ranging from 0·075 to 0·15 mm. Cylindrical walls are perforated by closely spaced and very fine pore-canals but no bifurcation of the latter is observed. Differs from the foregoing species [*Anthra-*

EXPLANATION OF PLATE 31

Figs. 1–3. *Nanopora anglica* gen. et sp. nov., ×230. 1. Holotype. Oblique section, showing at the top the pores widening from the interior to the exterior, and near the base variation in shape of the cross-sections of the pores. The circular cavity filled with matrix seen about half-way up the left-hand side, and the two similar cavities near the top of the specimen are considered to be traces of boring creatures, not reproductive bodies. Top bed, Hardrow Scar Limestone, Hardrow Scar, Yorkshire. B.M. (N.H.). Registered number V.45813. 2. Fragment to show curvature of the calcareous envelope. Same horizon and locality. Wood collection, slide W560. 3. To show variation in size and spacing of pores, also their elliptical nature and verticillate arrangement. Note constriction near upper end, also seen in the specimen figured in Plate 32, fig. 2. Same horizon and locality. Wood collection, slide W561.

EXPLANATION OF PLATE 32

Figs. 1–4. *Nanopora anglica* gen. et sp. nov., ×230. 1. Oblique section, to show (rarely found) difference at two ends. Either the calcareous tube is sharply bent out of the plane of the section at the top end, or this represents the growing point of the plant. Top bed, Hardrow Scar Limestone, Hardrow Scar, Yorkshire. B.M. (N.H.). Registered number V.45813. 2. Section showing expansion of interior cavity, followed by constriction (see p. 183). Same horizon and locality. Wood collection, slide W562. 3. Sections of calcareous tubes associated with *N. anglica*, possibly representing fragments of holdfast. Same horizon and locality. B.M. (N.H.). Registered number V.45813. 4. Cross-sections of calcareous tube, to show general appearance and variation. The bifid appearance seen in the calcareous wall of the upper section is due to alternating pores from a verticil at a different level being cut by the section. Same horizon and locality. B.M. (N.H.). Registered number V.45813.



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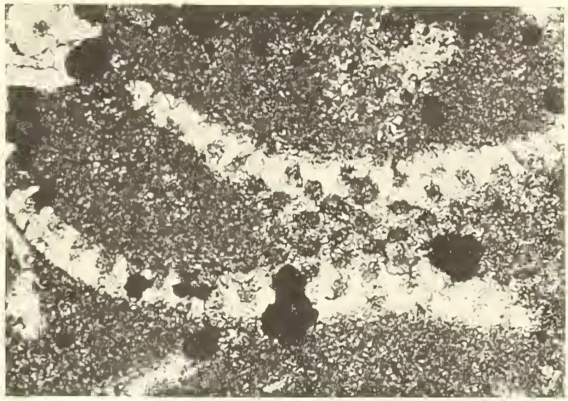

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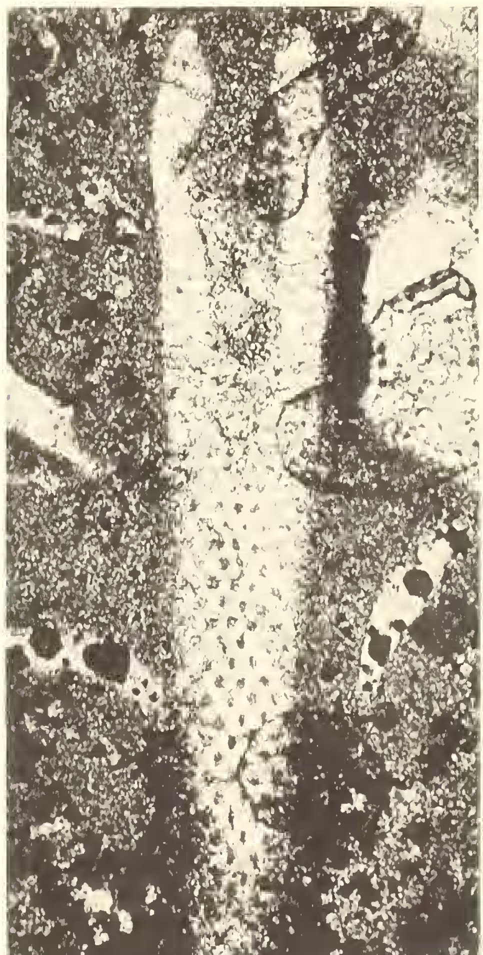

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WOOD, *Nanopora*